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Determination of Harmful Quantities and Rates of Penalty for Hazardous Substances. Volume I. Executive Summary

Battelle-Northwest, Richland, Wash Pacific Northwest Lab

Prepared for

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U.S. legislation requires the formulation of regulations designating specific hazardous substances and the delineation of harmful quantities for these substances. Penalty rates are to be established for spillage of non-removable hazardous substances to motivate greater efforts in the area of spill prevention. The objective of the subject study was to examine several technical alternatives for developing harmful quantity and penalty rate regulations. Four such methodologies are reported.

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FINAL REPORT

VOLUME I - EXECUTIVE SUMMARY

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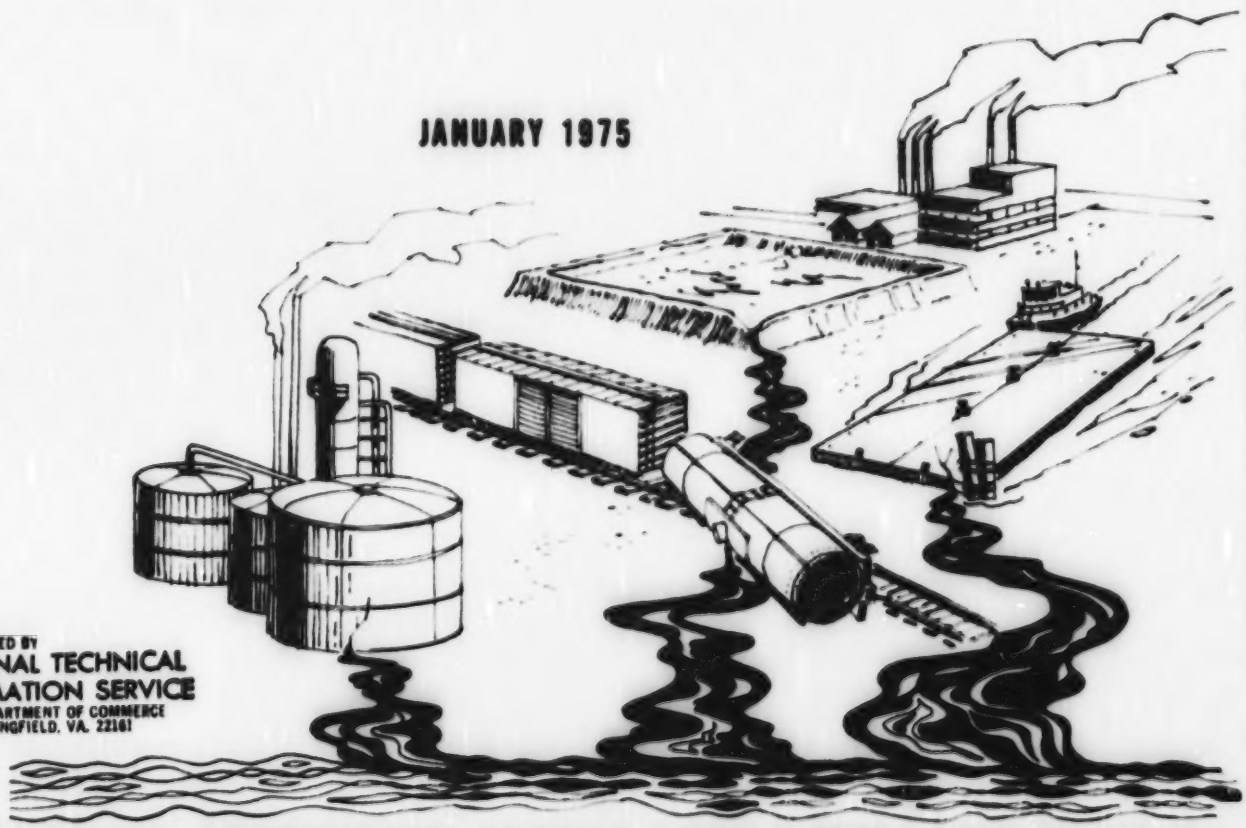

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by

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OCTOBER 1974

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HAZARDOUS SUBSTANCES BRANCH
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TABLE OF CONTENTS

	Page
INTRODUCTION	I-1
UNDERLYING CONCEPTS COMMON TO THE DEVELOPMENT OF ALL APPROACH METHODOLOGIES.	I-3
THE PRACTICALITY OF IMPLEMENTATION AND ENFORCEMENT OF THE METHODOLOGIES	I-3
USE OF PURE COMPOUNDS	I-3
DESIGNATION OF UNITS OF MEASUREMENT	I-3
SELECTION CRITERIA FOR ESTABLISHING CRITICAL CONCENTRATION	I-4
THE RESOURCE VALUE METHODOLOGY	I-5
BRIEF	I-5
VALUE THRESHOLD	I-5
SELECTION OF THE CRITICAL VOLUME FOR LAKES	I-5
SELECTION OF THE CRITICAL VOLUME FOR ESTUARIES	I-7
SELECTION OF THE CRITICAL VOLUME FOR RIVERS	I-7
SELECTION OF THE CRITICAL VOLUME FOR COASTAL WATERS	I-7
CALCULATION OF HARMFUL QUANTITY	I-8
INITIAL RATE OF PENALTY	I-8
ADJUSTMENT FACTOR	I-8
THE MODIFIED IMCO/GESAMP METHODOLOGY	I-11
BRIEF	I-11
PROFILING AND CATEGORIZING HAZARDOUS MATERIALS	I-11
DETERMINATION OF HARMFUL QUANTITY	I-14

TABLE OF CONTENTS (Cont'd.)

DETERMINING THE BASE RATE OF PENALTY I-15

FINE DETERMINATION I-15

THE UNIT OF MEASUREMENT METHODOLOGY I-17

BRIEF I-17

GENERAL CONCEPTS I-17

UNIT OF MEASUREMENT AND HARMFUL QUANTITY DETERMINATION I-17

COMPUTING THE BASE RATE OF PENALTY I-19

THE DOHM METHODOLOGY I-21

BRIEF I-21

HARMFUL QUANTITY DETERMINATION I-23

Stream Model I-23

Lake Model I-24

Estuarine Model I-24

Ocean Model I-25

Locational Factor I-25

RATE OF PENALTY DETERMINATION I-25

Stationary Sources I-25

Barges I-26

Railroads I-26

Trucking I-26

Determination of the Final Rate of Penalty I-26

LIST OF FIGURES

Number		Page
I-1	FLOW DIAGRAM FOR RESOURCE VALUE METHODOLOGY	I-6
I-2	FLOW DIAGRAM FOR IMCO METHODOLOGY	I-12
I-3	FLOW DIAGRAM FOR UNIT OF MEASUREMENT METHODOLOGY	I-18
I-4	FLOW DIAGRAM FOR DOHM - COST OF PREVENTION METHODOLOGY	I-22

LIST OF TABLES

Number		Page
I-1	SUMMARY OF CRITICAL CONCENTRATIONS AND RESULTING HARMFUL QUANTITIES FOR IMCO HAZARD CATEGORIES	I-14
I-2	UNITS OF MEASUREMENT AND HARMFUL QUANTITIES FOR UNIT OF MEASUREMENT METHODOLOGY	I-19

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FOREWORD

This report was initiated by the Environmental Protection Agency to gather additional information and to complete several concepts developed by the technical staff of the Agency. This report is one of the series dealing with hazardous materials and the prevention and/or removal of spills of these materials into or upon the navigable waters of the United States. The methodologies were determined to be necessary to provide a technical basis for the development of regulations under Section 311 of Water Pollution Control Act as amended in 1972 (PL 92-500). This report is a result of several man years of work by the Government, industry, and the contractor. It should be understood that the methodologies explained here may be used in some modified form in regulations to be developed and/or revised as appropriate to implement Section 311.

This document should be regarded as a technical reference document which may be used as appropriate by this Agency and others primarily in the development of the regulatory control program for hazardous substance spills. The principal regulations for which these methodologies were developed are required to be promulgated under Section 311(b)(2)(B)(iv) and Section 311(b)(4) which require that penalty rates for nonremovable hazardous substances shall be prescribed and that quantities determined to be harmful to public health and welfare be identified. The other regulations as required by Section 311 dealing with hazardous substances involve: the designation and determination of removability; the determination of removal and mitigating methods; the determination of procedures and equipment for spill prevention; the determination of small facility spill clean-up liabilities; the determination of nonharmful quantities; and appropriate revision to the National Oil and Hazardous Substance Pollution Contingency Plan. This information is thought to be of use of assessing the environmental benefits and potential economic impacts in the development of regulations dealing with methods for removal and mitigation of hazardous substances and procedures and equipment for prevention of hazardous substance spills from transportation, production and use facilities.

At the time the project was conceived the Agency had participated in international hazardous material control negotiations and had gained considerable experience working with industry in the production, distribution and use of materials which may be designated as hazardous substances. Late in 1972 and early in 1973, it became the concern of this Agency that several alternative methods should be examined in detail to allow equitable regulatory development. This concern was keyed to be pending designation regulation which would list elements and compounds as hazardous substances.

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It is anticipated that the information that has been gathered during this study which involved the National Hazardous Materials Conference in San Francisco, August 1974, and the Regulation Symposium in Washington, DC in October 1974 will be utilized in part in the development of regulations to be published in the Federal Register. Once the regulations are promulgated, going through the process of Advance Notice of Rule Making, Proposed Rule Making, and Final Promulgation, the program will be implemented nationwide. This program implementation is anticipated to be in conjunction with the United States Coast Guard and to be implemented at the EPA Region and Coast Guard District Level. It is further anticipated that areas for the Administrator's discretion in evaluating penalties may be established as appropriate through EPA Guidelines and/or Enforcement Regulations formulated by this Agency.

Particular thanks should be expressed to the primary authors of this Report with special emphasis to acknowledge the cooperation provided by the chemical manufacturing industry, the chemical transporting industry and others who supplied basic information upon which this study is built. An individual appreciation is expressed to Dr. Allen L. Jennings of the Hazardous and Toxic Substances Branch for his technical participation and enthusiasm is seeing this job completed. Others who helped in the review and editing for EPA included Dr. Gregory Kew, Messrs. Robert Sanford, James Cating, and Charles Gentry. It should be recognized that this project was possible due to the foresight in planning, funding, and the staff assistance of Messrs. Walter Miguez, Robert Suzuki, John Cox, and others of the Division of Oil and Special Materials, without whose help this project would have been impossible.

Dr. C. Hugh Thompson
Chief
HAZARDOUS SUBSTANCES BRANCH
Environmental Protection Agency

INTRODUCTION

Section 311 of Public Law 92-500 requires the formulation of regulations designating specific elements and compounds as hazardous substances and the subsequent delineation of harmful quantities for these substances. In addition, penalty rates are to be established for spillage of non-removable hazardous substances to motivate greater efforts in the area of spill prevention.

The objective of the subject study was to examine several technical alternatives for developing harmful quantity and penalty rate regulations. A minimum of three distinct methodologies were to be developed for defining harmful quantities of designated hazardous substances and for establishing penalty rates. Four such methodologies were formulated.

Each methodology is characterized by three identifiable segments: 1) a mechanism for deriving harmful quantities, 2) a rationale for the base rate of penalty, and 3) a scaling function to vary rates of penalty on the basis of the physical, chemical, and toxicological properties of individual materials. Additionally, two approaches offer locational variables which further refine penalty assessments based on the actual water uses and dispersive capacity of the receiving body. Each of these segments has been designed in modular fashion to allow the intermixing of preferred segments to form cohesive hybrid methodologies.

This volume is parallel to Volume II where one can find the specifics of the methodologies developed. Detailed data and background information are appended in Volume III.

UNDERLYING CONCEPTS COMMON TO THE DEVELOPMENT OF ALL APPROACH METHODOLOGIES

Although the intent of the work reported herein has been the development of diverse methodologies for quantitatively defining harmful quantities and setting rates of penalty for the spillage of non-removable hazardous substances, there are many underlying concepts common to all of the approaches. Four of these merit discussion prior to presentation of the individual methodologies: 1) the practicality of implementation and enforcement of the methodologies; 2) the use of pure compound data and the subsequent need for adjustment when spills involve solutions or mixtures; 3) the manner of dealing with units of measurement; and 4) the selection criteria for assigning critical concentrations.

THE PRACTICALITY OF IMPLEMENTATION AND ENFORCEMENT OF THE METHODOLOGIES

Regulatory mechanisms must typically strike a balance between features which add resolution and those which enhance the practicality of implementing and enforcing a regulation. With respect to regulations designating harmful quantities and penalty rates for hazardous material spills, the former features would be those aimed at post-spill investigations and damage assessment, while the latter would be encompassed in a single standard for all circumstances.

Neither extreme is deemed appropriate. However, it was assumed that approaches must be designed to be workable both for the regulatory agency and those being regulated. This led to a certain degree of simplification such as the grouping of potential receiving waters into four classifications based on hydrodynamic differences: lakes, rivers, estuaries, and coastal waters.

USE OF PURE COMPOUNDS

All methodologies have been designed to function on a pure compound basis. Additionally, each can deal with mixtures, some more readily than others. Output and input data requirements have been focused on the elements and compounds designated as non-removable hazardous substances.

DESIGNATION OF UNITS OF MEASUREMENT

It was determined that for most hazardous materials, there is no single unit of measurement upon which rates of penalty can be founded. Consequently, rather than derive a unit independently for each substance, for three of the four methodologies developed, the unit of measurement was derived after a base rate of penalty was determined. Typically, this unit was a multiple of common mass units.

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SELECTION CRITERIA FOR ESTABLISHING CRITICAL CONCENTRATIONS

There is no clear threshold such that spillage of more than a given amount of a contaminant constitutes harm at all locations and at all times while lesser amounts of the contaminant are totally harmless at all locations and at all times. Rather, the harm produced by the introduction of any pollutant into water is a continuous function dependent upon receiving water characteristics and measured in degrees of severity. The concentration at which the severity of resulting harm is deemed substantial is defined as the critical concentration. This concentration is subsequently employed as a measure of the relative toxicity of each material for the purpose of determining harmful quantities and rates of penalty by any of the four methodologies developed.

There are multiple types of harm that can be produced by hazardous materials as a result of the material's intrinsic properties and the extrinsic circumstances surrounding the spill itself, as well as the water uses associated with the receiving water. The authors chose to focus attention on acute toxicity to aquatic life as the major type of harm of concern for selecting critical concentrations. Whenever possible, the concentration of choice was the 96 hour LC_{50} to median sensitive receptors. The latter were defined as Lepomis macrochirus (Bluegill sunfish) or Pimephales promelas (fathead minnow) for freshwater. For saline waters, preference was given to 96 LC_{50} data for species of commercial and recreational value: Ostrea (oysters), Mercenia mercenia (hard clams), and Penaeus (shrimp). Other species commonly employed for bioassay work were ranked in order of preference. When data were available on species of similar sensitivity, highest priority was given to test results in hard waters with an ambient pH range of 6.5-8.0.

THE RESOURCE VALUE METHODOLOGY

BRIEF

The methodology developed in the following discussion directs attention to the economic value of environmental resources and the potential loss as a result of the spillage of hazardous materials. Harm is defined as a threshold dollar value such that damage in excess of that amount is considered substantial. The threshold itself is selected through a decision analysis process with the intent of keeping the threshold in a reasonable range without encouraging the discharger to gamble by failing to report spills of quantities equal to or greater than the harmful quantity.

Rates of penalty are derived to be commensurate with the value of resources damaged. This provides for the internalization of the costs to society of individual spills. Whereas post-spill, site specific damage assessment studies generally are deemed unnecessarily expensive, adjustment factors are developed which may be used to modify penalties on the basis of key environmental parameters in the area of the spill. The information flow required for the Resource Value Methodology is illustrated in Figure I-1.

VALUE THRESHOLD

The Resource Value Methodology employs an economic standard for determining when harm is considered substantial. A threshold value is selected for this purpose such that the ability to contaminate, to the critical concentration, a quantity of water with a value equal to or greater than this threshold value qualifies the harm as substantial. The minimum quantity of hazardous material capable of that degree of contamination is the harmful quantity.

The threshold value was set at $10,000 since it was concluded that this amount was sufficient to justify the costs associated with processing and responding to a spill report but was not so excessive that it would provide incentive for the discharger to gamble by failing to report a spill of a harmful quantity. The $10,000 value threshold was converted into critical volumes for each of the water body types after correlation of economic values of representative receiving waters in the United States with water volume.

SELECTION OF THE CRITICAL VOLUME FOR LAKES

Data valuing lakes as a resource were collected for various regions of the country. In the past several basic valuation techniques

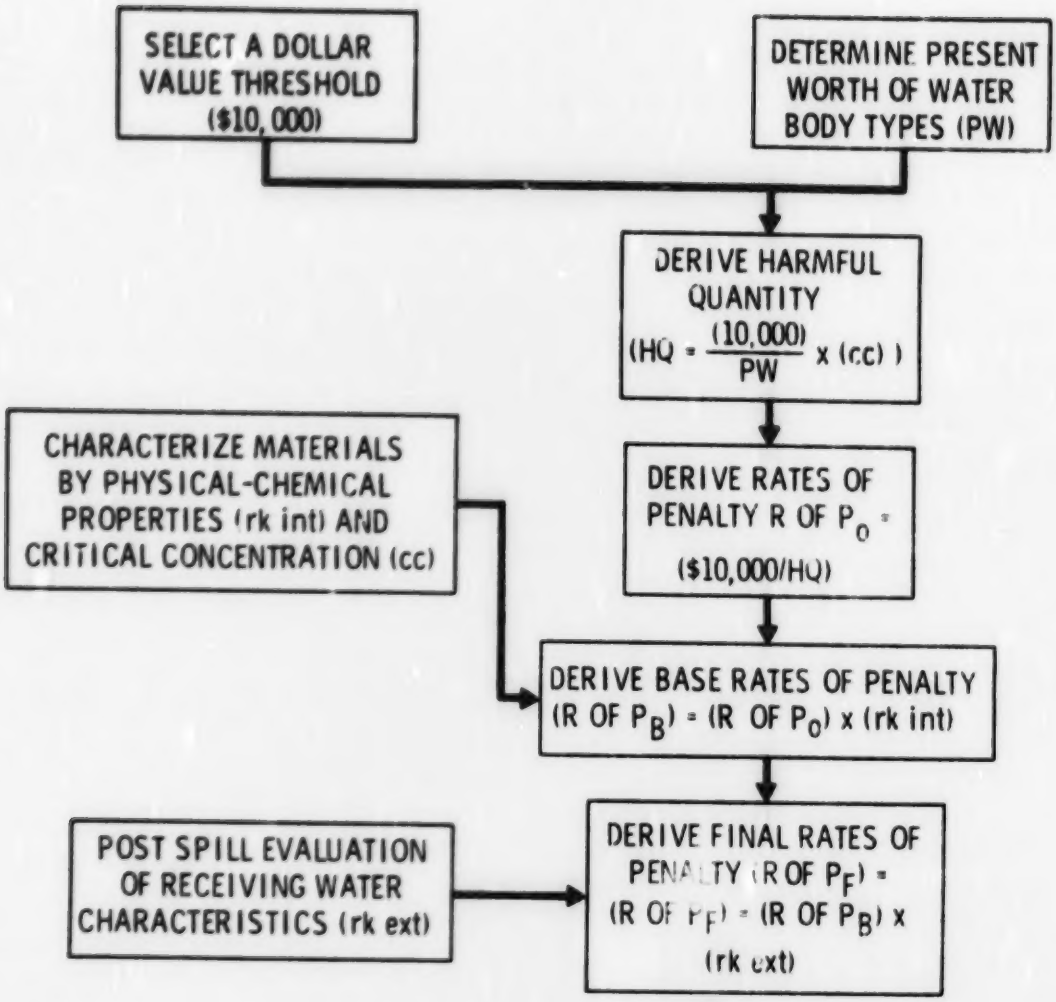
SELECT A DOLLAR VALUE THRESHOLD ($10,000)
DETERMINE PRESENT WORTH OF WATER BODY TYPES (PW)
DERIVE HARMFUL QUANTITY (HQ = (10,000)/PW x (cc))
CHARACTERIZE MATERIALS BY PHYSICAL-CHEMICAL PROPERTIES (rk int) AND CRITICAL CONCENTRATION (cc)
DERIVE RATES OF PENALTY R OF P_0 = ($10,000/HQ)
DERIVE BASE RATES OF PENALTY (R OF P_B) = (R OF P_0) x (rk int)
POST SPILL EVALUATION OF RECEIVING WATER CHARACTERISTICS (rk ext)
DERIVE FINAL RATES OF PENALTY (R OF P_F) = (R OF P_F) = (R OF P_B) x (rk ext)

FIGURE I-1. FLOW DIAGRAM FOR RESOURCE VALUE METHODOLOGY

have typically been employed. These yield a family of relations with increasing marginal values per unit volume as the size of the lake diminishes. Values based on recreational income (i.e., swimming, boating, fishing) were deemed the most appropriate since these water uses are those most commonly damaged by spill incidences.

Correlation analysis revealed that a lake with a present value of $5,000 would be 74,277 cubic meters (60 acre-feet) in size. This corresponds to an annual income value of $0.004 per cubic meter ($5 per acre-foot).

SELECTION OF THE CRITICAL VOLUME FOR ESTUARIES

Estuaries were valued on the basis of the income from commercial and sport fishing per unit of surface area obtained in representative estuarine locations. Values obtained described a well defined relation corresponding to the association of 1.6 hectare (3.9 acre) with a present worth of $5,000. An average depth of 3 meters (10 feet) was then assumed to yield a critical volume of 49,212 cubic meters (39 acre-feet) of estuarine water. Thus harmful quantities for materials with equivalent freshwater and saltwater toxicities will be twice as large for spills in lakes as for spills in estuaries.

SELECTION OF THE CRITICAL VOLUME FOR RIVERS

No valuation technique was deemed appropriate for correlating river size and value with data presently available. Consequently, the critical volume for rivers was taken as that derived for lakes. This results in a single harmful quantity for all freshwater systems.

SELECTION OF THE CRITICAL VOLUME FOR COASTAL WATERS

Coastal waters were valued as the sum of two unit values: one related to intrinsic values, and one related to the influence of coastal waters on the estuarine system. The intrinsic value was derived by summing the present worth of total annual income from commercial fishing, limited sport fishing, and recreational marine swimming, and dividing by the estimated volume of water contained in the 12 mile contiguous zone. This resulted in a present worth of $973 per million cubic meters ($1.20 per acre-foot).

The estuarine-related value was derived by estimating the potential for a spill in coastal waters to lead to estuarine contamination. An average tidal interchange of 50 percent was assumed. At the same time, it was determined that estuaries constitute one percent of the volume of water contained in the contiguous zone. Therefore,

coastal waters were given an estuarine-related value equal to 0.005 that of the estuaries themselves, or $508 per million cubic meters (0.64 per acre-foot).

Summing the two components yields a present worth of $1511 per million cubic meters ($1.84 per acre-foot). In turn, this corresponds to a critical volume of 3,310,000 cubic meters (2,717 acre-feet).

CALCULATION OF HARMFUL QUANTITY

Harmful quantities have been defined as that amount of hazardous material required to bring the critical volume to the critical concentration level. Therefore, each hazardous material is associated with three harmful quantities: Freshwater (rivers and lakes), estuaries, and coastal waters. Harmful quantities can be calculated by taking the product of the critical volume of the water body type of interest, and the critical concentration for the hazardous material of interest.

INITIAL RATE OF PENALTY

The Resource Value Methodology is built around the rationale that penalties for spills of non-removable hazardous substances should be equivalent in value to the damages to the environment caused by the spill. Since the various water bodies have been valued, and a harmful quantity (HQ) has been defined as an amount sufficient to contaminate water with a present value of $5,000, the initial rate of penalty (R of P_O) is simply defined as:

$$R \text{ of } P_O = \$5{,}000/HQ$$

ADJUSTMENT FACTOR

The initial rate of penalty (R of P_O) was designed to recover the value of potential damages to the environment. The underlying rationale for Resource Value Methodology rates of penalty, however, was to recover the value of actual or probable damages. Hence, adjustment factors are necessary to reflect the fact that degradability and dispersibility characteristics can mitigate the effects of a spill. The overall adjustment factor is composed of four individual multiplicative components: two related to intrinsic properties, and two related to extrinsic parameters.

The intrinsic components are employed to convert the initial rate of penalty to a base rate of penalty for each substance, a priori. One component reflects the likely duration of effects stemming from a spill. The second modifies the base rate of penalty further as a function of the solubility, volatility, and specific gravity of the substance which will enhance or inhibit the movement of the material through the environment. The combined effect

of these factors is sufficient to change the initial $5,000/HQ penalty rate by a factor of 0.016 - 0.36.

Extrinsic components in the adjustment factor are designed to be applied after a spill has occurred. The first component adjusts the base rate of penalty as a function of the relative recreational value of the receiving water compared to that used to derive the critical volumes. The second component takes into account the actual dispersive capability of the receiving water in comparison to the instantaneous mixing assumption made to derive the initial rate of penalty. These components are optional and may modify the penalty either upward or downward.

Final rates of penalty can be calculated as the produce of the initial rate of penalty and the adjustment factor with or without inclusion of the extrinsic components.

THE MODIFIED IMCO/GESAMP METHODOLOGY

BRIEF

In this approach, hereafter referred as the IMCO Methodology, a procedure is developed for designating harmful quantities and rates of penalty based on a proposed international hazardous material rating/classification system which has been submitted under the auspices of the United Nations to its member nations for adoption. When adopted, this system will be used to regulate the operation of ships transporting hazardous materials in bulk. Because the proposed shipping regulations do not embrace the concepts of harmful quantity and rate of penalty, it was necessary, during the course of this study, to introduce a number of modifications to the basic IMCO rating/classification system in order to comply with the requirements of Section 311.

As an overview, the IMCO Methodology first utilizes the rating/classification system developed by an ad hoc committee of experts from the Inter-Governmental Maritime Consultative Organization (IMCO) and the Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) to profile hazardous materials on the basis of their relative hazard potentials. These profiles are then used to relegate the hazardous materials to hazard categories depending upon the degree to which they are expected to exert their various hazard potentials. Next, a critical concentration is determined for each category. The Resource Value Methodology rationale is then used to derive a harmful quantity and base rate of penalty for each category. The base rate of penalty is then modified for individual hazardous materials by an adjustment factor which considers the ability of the material to exert its full hazard potential(s) in a given water body type when consideration is given to the physical/chemical properties of the hazardous material. For reader convenience, the steps in developing the IMCO Methodology are shown schematically in Figure I-2.

PROFILING AND CATEGORIZING HAZARDOUS MATERIALS

The IMCO Methodology offers simplification of the basic harmful quantity/rate of penalty regulatory mechanism by addressing groups of materials with similar properties and hazard rather than individual hazardous substances. To facilitate this, materials are profiled and categorized in two separate ways:

- On the basis of their relative hazard potentials using the rating/classification system developed by the ad hoc committee of experts from the Inter-governmental Maritime Consultative Organization (IMCO) and the Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP); and

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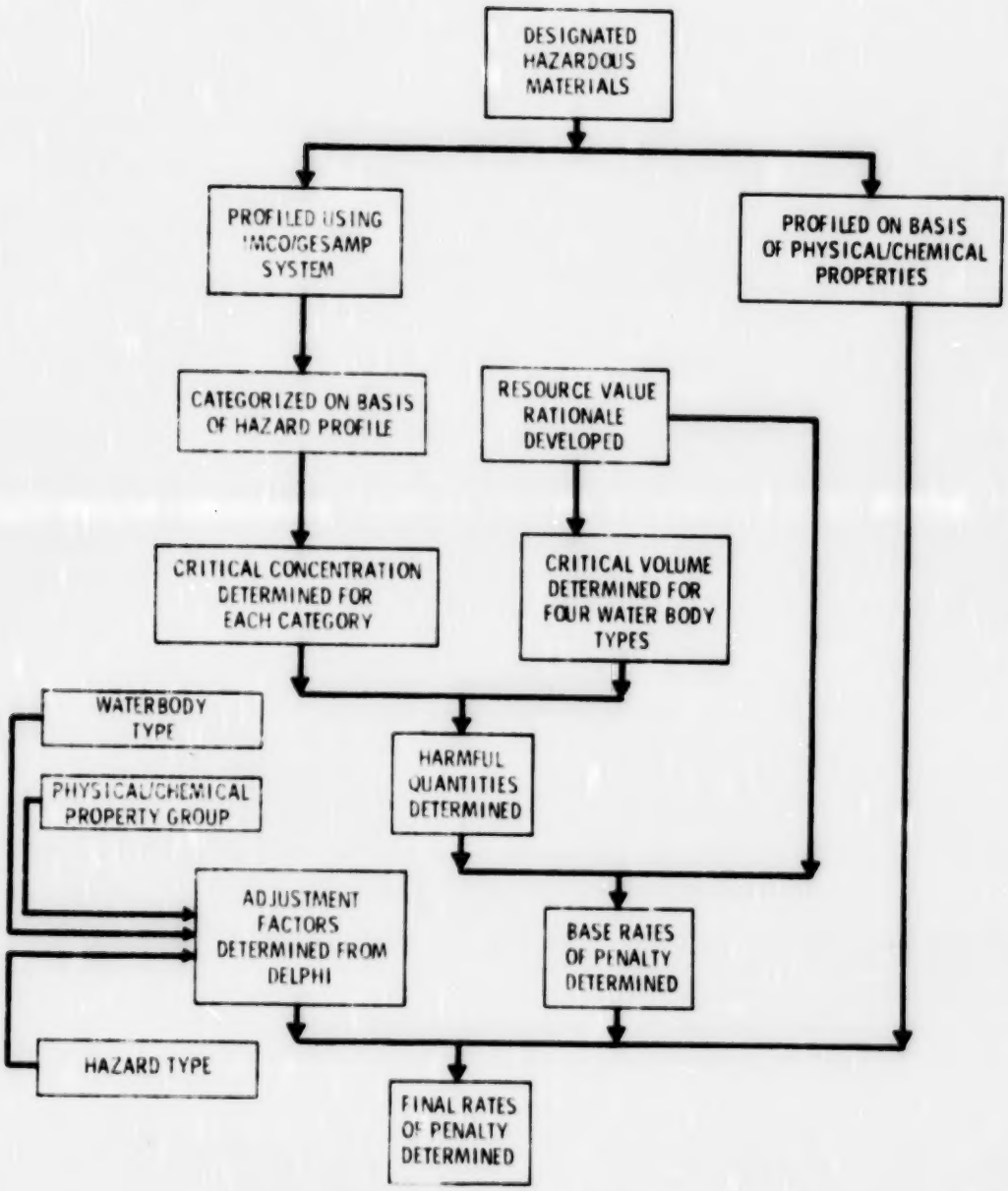
DESIGNATED HAZARDOUS MATERIALS
PROFILED USING IMCO/GESAMP SYSTEM
PROFILED ON BASIS OF PHYSICAL/CHEMICAL PROPERTIES
CATEGORIZED ON BASIS OF HAZARD PROFILE
RESOURCE VALUE RATIONALE DEVELOPED
CRITICAL CONCENTRATION DETERMINED FOR EACH CATEGORY
CRITICAL VOLUME DETERMINED FOR FOUR WATER BODY TYPES
WATERBODY TYPE
PHYSICAL/CHEMICAL PROPERTY GROUP
HARMFUL QUANTITIES DETERMINED
ADJUSTMENT FACTORS DETERMINED FROM DELPHI
BASE RATES OF PENALTY DETERMINED
HAZARD TYPE
FINAL RATES OF PENALTY DETERMINED

FIGURE I-2. FLOW DIAGRAM FOR IMCO METHODOLOGY

- On the basis of their physical/chemical properties using a system developed by the authors.

The first categorization scheme generates four hazard categories, while the second generates fourteen physical/chemical categories. Conceptually, each hazardous material is a member of each of the two types of categories. Procedures for deriving harmful quantities and rates of penalty utilize these groups as the basic working unit rather than the individual materials.

The first profiling operation considered five potential hazards:

- Bioaccumulation,
- Damage to living resources,
- Hazards to human health (oral intake),
- Hazards to human health (external exposure), and
- Reduction of amenities.

Each material was given a rating relative to its hazard potential in each of the five hazard areas. The aggregate of these ratings then determined in which of the four hazard categories the material will be grouped.

In general, Category A includes those materials which are bio-accumulative to toxic levels or toxic to aquatic life below 1 ppm, as flesh. Category B includes materials which concentrated in organisms over a short period of time, capable of tainting fish flesh, or toxic to aquatic life at levels of 1-10 ppm. Category C materials on toxic to aquatic life at levels of 10-100 ppm and Category D materials are toxic to aquatic life at levels of 100-1,000 ppm.

The second profiling operation was based on the physical/chemical properties of the hazardous materials. The purpose of this second profile was that of determining, at least in a general manner, the predicted behavior of a material when it is spilled into water.

Four properties were selected as being the most meaningful in terms of predicting general action patterns:

- Persistence,
- Density classification (float, mix, sink),
- Volatility, and
- Solubility.

The fourteen physical/chemical categories consist of the meaningful combinations of these four properties.

DETERMINATION OF HARMFUL QUANTITY

The IMCO Methodology defines substantial harm in the same manner as the Resource Value Methodology. That is, substantial harm is contamination to the critical concentration of waters with a present worth of $5,000 or greater. Consequently, the same critical volumes were employed to derive harmful quantities: 74,277 cubic meters (60 acre-feet) for lakes and rivers; 49,212 cubic meters (39 acre-feet) for estuaries; and 3,310,000 cubic meters (2,171 acre-feet) for coastal waters. At this point, however, individual critical co centrations were not utilized to determine harmful quantities. Rather, a critical concentration representative of each of the four hazard categories was employed. These critical concentrations and resulting harmful quantities are summarized in Table I-1.

TABLE I-1

SUMMARY OF CRITICAL CONCENTRATIONS AND RESULTING HARMFUL QUANTITIES FOR IMCO HAZARD CATEGORIES

IMCO Category	Critical Concentration (ppm)	Harmful Quantity, kg (lbs)		
		Lakes & Rivers	Estuaries	Coastal Waters
A	0.5	37 (83)	26 (54)	1,400 (3,100)
B	5.5	410 (910)	270 (610)	15,000 (34,000)
C	55.0	4,100 (9,100)	2,700 (6,100)	150,000 (340,000)
D	300.0	23,000 (49,000)	15,000 (32,000)	850,000 (1,900,000)

DETERMINING THE BASE RATE OF PENALTY

The rationale for the base rate of penalty assessed by the IMCO Methodology is the same as that developed for the Resource Value Methodology: the penalty is set at the value of the potential damage resulting from a spill. Therefore the base rate of penalty, R of P_B, was calculated as:

$$R \text{ of } P_B = \$5,000/HQ$$

where HQ is the harmful quantity.

FINE DETERMINATION

With the IMCO Methodology, the base rate of penalty is modified by an adjustment factor to determine the actual fine rate. The adjustment factor is a function of the physical/chemical category to which a material is assigned. It serves to diminish the penalty rate for those substances whose physical/chemical properties decrease the volume of water affected by a given spill. Since there are fourteen physical/chemical categories and four hazard categories, there are 56 rates of penalty possible for each water body type. The penalty assessed for a given spill is calculated as the product of the appropriate rate of penalty for the water body type and the quantity of material spilled.

THE UNIT OF MEASUREMENT METHODOLOGY

BRIEF

The Unit of Measurement (UM) Methodology addresses the letter of the law whereas the other methodologies utilize a technical or economical basis to satisfy the intent of the law. To this end, the derivation of this methodology is premised by the selection of a unit of measurement common to the usual trade practice. Harmful quantities and rates of penalty are then derived from this unit of measurement whose prime selection criteria are that it (1) be a unit common to usual trade practices, and (2) be large enough so that spillage of this quantity leaves little doubt that substantial harm will result. Rates of penalty are also derived from this unit of measurement through introduction of the fixed monetary guidelines established by Congress in Section 311(b)(2)(B)(iv) of Public Law 92-500. Hence, the UM Methodology employs an independently derived unit of measurement.

Figure I-3 provides a schematic representation of the UM Methodology which should facilitate reader understanding of ensuing sections.

GENERAL CONCEPTS

The Unit of Measurement Methodology stands apart from the other three approaches developed in that no attempt is made to establish a rationale for the penalty levels beyond their compliance with the mandate of Section 311(b)(2)(B)(iv) of Public Law 92-500. Indeed, the approach is designed as a literal interpretation of the law itself whereby the unit of measurement is derived independently and base rates of penalty are fixed once the unit is determined.

The UM Methodology is ideally suited for the grouping concept developed with the IMCO Methodology. Consequently, each material was dealt with as a member of a hazard category and a physical/chemical category in the same manner as in the latter approach.

UNIT OF MEASUREMENT AND HARMFUL QUANTITY DETERMINATION

The UM Methodology requires the independent selection of units of measurement for each material. Since a grouping concept was employed, only four units of measurement were required. The transportation frame of reference was selected as the most appropriate for prospective units.

Container sizes commonly utilized for the shipment of solid and liquid chemicals were placed on a scale of relative size. For both types of substances, a significant break was found between

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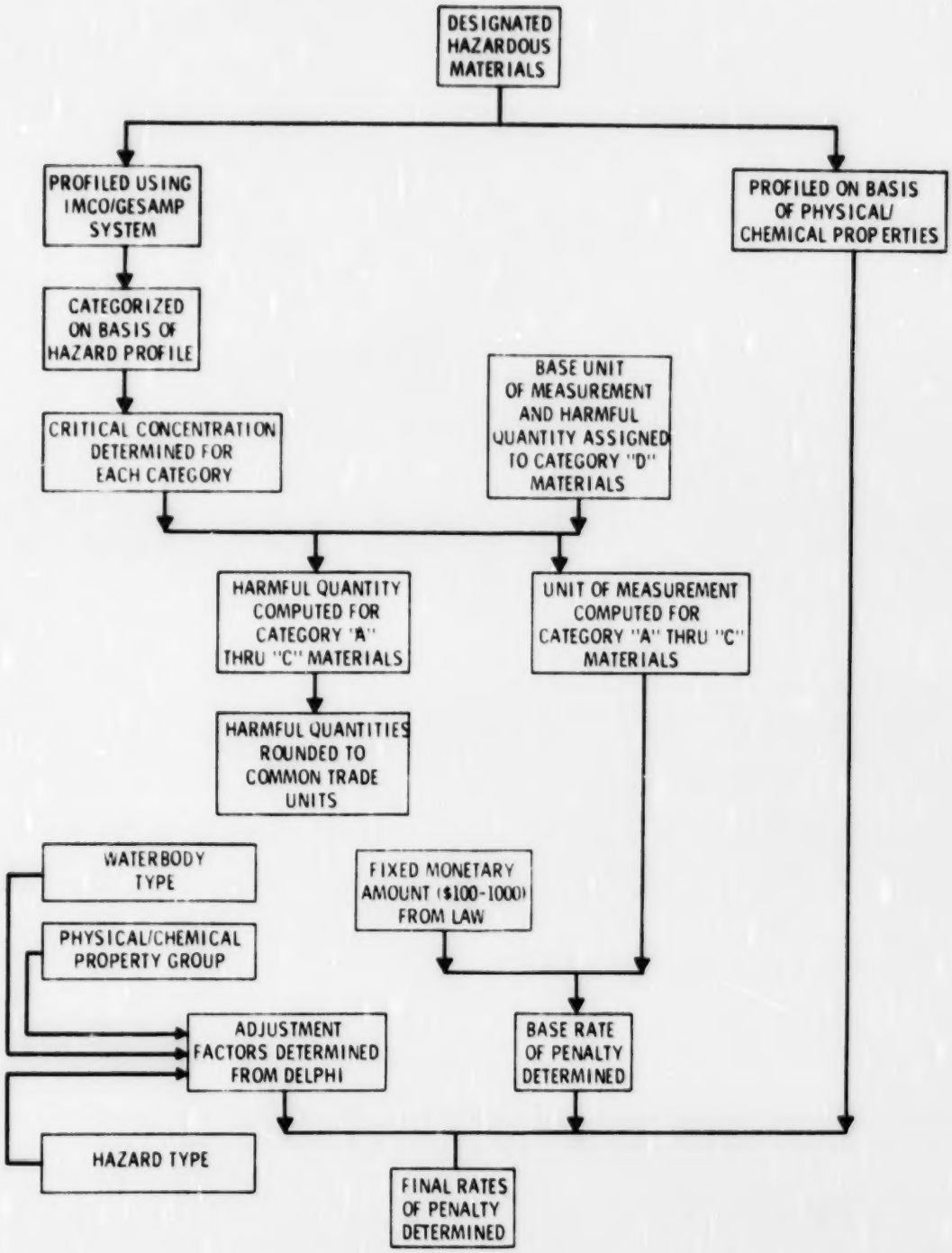
DESIGNATED HAZARDOUS MATERIALS
PROFILED USING IMCO/GESAMP SYSTEM
PROFILED ON BASIS OF PHYSICAL/ CHEMICAL PROPERTIES
CATEGORIZED ON BASIS OF HAZARD PROFILE
BASE UNIT OF MEASUREMENT AND HARMFUL QUANTITY ASSIGNED TO CATEGORY "D" MATERIALS
CRITICAL CONCENTRATION DETERMINED FOR EACH CATEGORY
HARMFUL QUANTITY COMPUTED FOR CATEGORY "A" THRU "C" MATERIALS
UNIT OF MEASUREMENT COMPUTED FOR CATEGORY "A" THRU "C" MATERIALS
HARMFUL QUANTITIES ROUNDED TO COMMON TRADE UNITS
WATERBODY TYPE
FIXED MONETARY AMOUNT ($100-1000) FROM LAW
PHYSICAL/CHEMICAL PROPERTY GROUP
ADJUSTMENT FACTORS DETERMINED FROM DELPHI
BASE RATE OF PENALTY DETERMINED
HAZARD TYPE
FINAL RATES OF PENALTY DETERMINED

FIGURE I-3. FLOW DIAGRAM FOR UNIT OF MEASUREMENT METHODOLOGY

the size of bulk shipment containers and individually packaged containers. For the less hazardous materials (IMCO Category D substances), it was assumed that the smallest bulk containers would be capable of producing substantial harm, if spilled, while the largest individual container would not. Consequently, a 15,142 liter (4000 gallon) tank car was selected as the unit of measurement of Category D materials as well as the harmful quantity. Units of measurement for Categories A through C were then assigned such that they formed the same ratio with the Category D unit of measurement as that formed by their respective critical concentrations. Units of measurement were then rounded to the size of the nearest shipment container and equated to the harmful quantity. This resulted in the harmful quantities given in Table I-2.

TABLE I-2

UNITS OF MEASUREMENT AND HARMFUL QUANTITIES
FOR UNIT OF MEASUREMENT METHODOLOGY

Category	Critical Concentration (ppm)	Unit of Measurement and Harmful Quantity (volume)	Unit of Measurement and Harmful Quantity (mass)
A	05	18.93ℓ 5 gal	22.68 kg 50 lbs
B	55	288.20ℓ 55 gal	226.80 kg 500 lbs
C	55	2081.98ℓ 350 gal	2721.55 kg 5000 lbs
D	300	15.41 m^3 4000 gal	14.51 MT 16 tons

COMPUTING THE BASE RATE OF PENALTY

With the units of measurement independently derived as outlined above, the base rate of penalty is specified as $1000 per unit of measurement.

As in the IMCO Methodology, the penalty is adjusted downward as a function of the physical/chemical category to which the material is assigned. Each category is assigned an adjustment factor in the range 0.1 - 1.0 which reflects the relative ability of materials in that category to disperse and exert their hazard potential. Application of this factor to the base rate of penalty results in a minimum fine of $100/unit of measurement and a maximum fine of $1000/unit of measurement as prescribed by Section 311 (b)(2)(B)(iv).

THE DOHM METHODOLOGY

BRIEF

The methodology developed within this portion of the study is an extension of an approach formulated by the Division of Oil and Hazardous Materials (DOHM), U. S. Environmental Protection Agency, for assessing the impacts of hazardous material spills in streams. This approach uses a simplified plug flow model to assess the quantity of a hazardous material (harmful quantity) which when spilled is capable of inflicting substantial harm to key aquatic organisms in a stream. The wide applicability of Section 311 requires that harmful quantities for other types of water bodies such as lakes, estuaries, and coastal zones be determined. To this end, the basic DOHM plug flow model has been extended and modified whenever possible to meet these requirements.

The objective of this approach is that of defining a critical volume, the contamination of which results in substantial harm. For the stream and estuary categories, statistical samples of U. S. water bodies were analyzed to determine this critical volume. Simplified plug flow models of these water bodies were then used to determine harmful quantities based on the amount of hazardous substance required to bring the critical volume to the critical concentration level. Harmful quantities for lakes and coastal zones were extrapolated from the stream and estuary harmful quantities, respectively.

Determination of the rate of penalty is independent of that of the harmful quantity in the DOHM Methodology. For this approach, the rate of penalty is equated to the cost which would have been incurred by the discharger had he instituted measures to prevent the spill.

Separate "costs of prevention" have been determined for both stationary and mobile sources. The latter includes transportation by rail and barge.

A method is presented for employing the cost of prevention to derive the rate of penalty. The base level cost of prevention can be utilized directly as the penalty rate or an adjustment factor can be utilized to vary the cost of prevention as a function of chemical characteristics of each substance.

Figure I-4 represents the flow diagram of the procedure required by the DOHM Methodology to develop a harmful quantity and rate or penalty for any substance.

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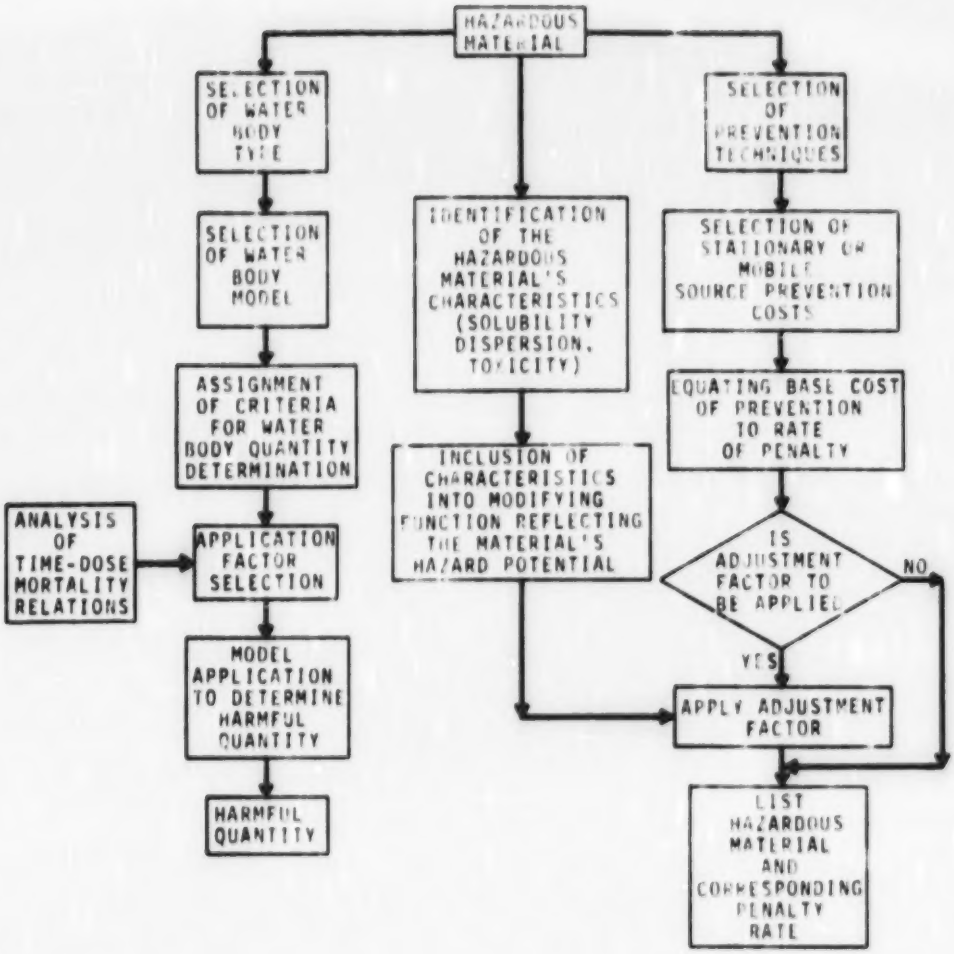
HAZARDOUS MATERIAL
SELECTION OF WATER BODY TYPE
SELECTION OF WATER BODY MODEL
ASSIGNMENT OF CRITERIA FOR WATER BODY QUANTITY DETERMINATION
ANALYSIS OF TIME-DOSE MORTALITY RELATIONS
APPLICATION FACTOR SELECTION
MODEL APPLICATION TO DETERMINE HARMFUL QUANTITY
HARMFUL QUANTITY
IDENTIFICATION OF THE HAZARDOUS MATERIAL'S CHARACTERISTICS (SOLUBILITY DISPERSION, TOXICITY)
INCLUSION OF CHARACTERISTICS INTO MODIFYING FUNCTION REFLECTING THE MATERIAL'S HAZARD POTENTIAL
SELECTION OF PREVENTION TECHNIQUES
SELECTION OF STATIONARY OR MOBILE SOURCE PREVENTION COSTS
EQUATING BASE COST OF PREVENTION TO RATE OF PENALTY
IS ADJUSTMENT FACTOR TO BE APPLIED
NO
YES
APPLY ADJUSTMENT FACTOR
LIST HAZARDOUS MATERIAL AND CORRESPONDING PENALTY RATE

FIGURE I-4. FLOW DIAGRAM FOR DOHM - COST OF PREVENTION METHODOLOGY

HARMFUL QUANTITY DETERMINATION

The DOHM Methodology defines substantial harm in a statistical manner through use of an idealized plug flow model. Significant differences in the hydrodynamic characteristics with the water body types considered requires that each be evaluated separately.

Stream Model

For flowing streams, an idealized plug flow model of the form

$$T = KM/CQ$$

was employed where

T = time for the plug to pass a point in the stream

M = mass of hazardous substance spilled

Q = stream flow rate

C = concentration of hazardous substance, and

K = conversion constant.

If the critical concentration is substituted in the above equation as the C term, the mass term, M, becomes the harmful quantity. Since the critical concentration was specified as a 96 hour LC_{50} value for a median receptor, T was set as 96 hours. A review of fish kill reports revealed that these incidences are typically 6-96 hours in duration. When time-dose mortality relations for hazardous substances were studied, it was further noted that greater harm could occur from spills condensed to a 6 hour-long plug than the same spill diluted to a 96 hour-long plug. Consequently, an application factor was included in the constant (K) to convert T from 96 to 6 hours and the critical concentration (C) to the appropriate value for a 6 hour exposure period.

The flow rate (Q) was determined statistically from data for streams throughout the United States. This was done by calculating the volume of water flowing at any one time in streams in the United States and corresponding flow rate of the stream. This data was accumulated and summed for the Nation as a whole. It was determined that 95 percent of all stream water in the country flows in streams with a median flow rate of 1 m^3/sec (36 cfs) or greater. Therefore, 36 cfs was employed in the plug flow model.

The model was then solved for M for each hazardous material employing the respective critical concentration, and M was designated the harmful quantity.

Lake Model

No statistical data were available on lakes which would permit determination of harmful quantities in a manner similar to that employed for streams. Consequently, harmful quantities for spills into lakes were equated to those for rivers thus yielding a single freshwater harmful quantity. This is equivalent to defining the critical volume for lakes as 21,600 cubic meters (17.5 acre-feet) based on the 36 cfs flow over a six hour period of time.

Estuarine Model

The plug flow model for the stream was modified for application to estuaries yielding

$$C = M/(Qt + RP/D)\ (T)\ K$$

where

R = tidal exchange ratio

P = tidal prism upstream from the spill discharge point

D = duration of tidal cycle (24 hours, 50 minutes)

Qt = tributary discharge

C = concentration of hazardous material in the combined flow

M = quantity of material spilled

T = time for the plug to pass a point

RP/D = effective flow of new ocean water passing the discharge point

K = conversion constant including the application factor derived for the stream model.

Conservation of mass was applied and the equation rearranged to become

$$M = K \left(\frac{So}{So-Se}\ Qt\right)\ (T)\ (C)$$

where

So = salinity of ocean water, and

Se = salinity of water leaving the estuary.

Values of 34 ppt and 31 ppt were assumed for So and Se, respectively. A value of 96 hours was assumed for T since C was set at the critical concentration. A statistical analysis similar to that performed for the streams was made for tributaries flowing into estuaries. It was determined for the United States that 95 percent of all estuarine inflows are carried by streams with a median flow rate of 200 cfs or greater. This value then was put into the formulation as Qt, and M calculated for each hazardous substance. M was then designated as the harmful quantity for spills into estuaries.

Ocean Model

It was assumed that the major threat from spills into ocean water results from the potential for these materials to move into an estuarine system. Therefore, the harmful quantity for coastal waters is equated to that for estuaries. This is equivalent to defining the critical volume of approximately 1,370,000 cubic meters (1120 acre-feet).

Locational Factor

Two potential modifications were derived to better suit the models to large water bodies. The first involves the designation of individual harmful quantities for specific stationary sources through the use of the actual stream flow in the plug flow model. The second recognizes the greater assimilative capacity of rivers carrying barge traffic. A statistical analysis on these rivers revealed that 95 percent of them have a median flow of 172 m^3/sec (6150 cfs) or greater. Use of this flow in the harmful quantity formulations yields harmful quantities for barges 172 times as large as those for streams in general.

RATE OF PENALTY DETERMINATION

The rationale for rates of penalty in the DOHM Methodology is that penalties should exceed the cost of spill prevention and thus provide positive incentive for dischargers to maintain effective spill prevention programs. Since spill prevention is associated with different base costs for various spill sources, rates of penalty must be assigned individually to the various sources.

Stationary Sources

Data was collected from two major MCA member chemical producers on the cost of spill-proofing a production facility. Spill-proofing was defined as containment with facilities to remove the spilled material to storage or treatment areas. These measures were assumed to be 100 percent effective. Costs were then allocated over the total volume of product likely to have been spilled over the life of the equipment had not the spill

precautions been taken. The numbers thus derived from the two sources were in close agreement and were averaged to yield the cost of prevention for stationary sources of $8.82/kg ($4.00/lb).

Barges

The cost of prevention estimate for spills from barges is based on the cost of converting single-hulled Type III barges to double-hulled Type III barges and the estimated spillage prevented by this conversion over the life of the barge. Data from an MCA member firm and a twenty-two member survey conducted by the MCA generated a cost of $11.39/kg ($5.17/lb).

Railroads

The cost of prevention estimate for spills from rail transport is based on the average cost increasing the integrity of tank cars for shipping parathion and phenol. For parathion, costs reflected the addition of head shields and conversion to F couplings. Phenol car costs included an added expense for conversion from internally coiled to externally coiled cars. These measures were assumed to be 100 percent effective in preventing leaks after derailments. Therefore, costs were allocated over the average per car spillage estimated from historical data for the life of the car. This yields an average cost of prevention for rail of $0.84/kg ($0.37/lb).

Trucking

Insufficient data were available to estimate the cost of prevention for trucking based on improving the integrity of tank trucks. At the same time, data that were reviewed indicated that 95 percent of all truck related spills occur at loading and unloading facilities. Consequently, the cost of prevention for spills from trucks was equated to that for stationary sources.

Determination of the Final Rate of Penalty

The base rate of penalty was equated to the cost of prevention for the various spill sources. An adjustment factor was then derived to modify penalties upward for the more persistent and toxic substances. The adjustment factor is comprised of these multiplicative factors: a toxicity term, a dispersal term, and a degradability term. Each term was quantitatively derived from physical/chemical data for the specific hazardous substance of interest. The adjustment factor can increase the rate of penalty by a factor of two, which approximates the additional costs required for spill prevention when substances are highly flammable or corrosive.

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